PRELIMINARY INSTRUCTION MANUAL
FOR THE
BA-1C BOLOMETER PREAMPLIFIER
SERIAL NO. 147 AND ABOVE

Weinschel Engineering
KENSINGTON, MARYLAND

WEINSCHEL ENGINEERING
KENSINGTON, MARYLAND
TEST RECORD

BOLOMETER PREAMPLIFIER — MODEL BA-1C

DATE 3-18-60 — SERIAL NUMBER 255

CUSTOMER _____ — JOB NUMBER _____

1. Gain:

Input = 1.0 MV — Output 10.5 V rms

2. Linearity:

Input	DEVIATION	Deviation from Linear
3 MV	0 db	0 db
-2 db	0 db	Less than .05 db
-6 db	+.005 db	" " " db
-10 db	+.007 db	" " " db
-14 db	+.009 db	" " " db
-18 db	+.010 db	" " " db
-24 db	+.011 db	" " " db
-30 db	+.013 db	" " " db

3. Gain Stability:

Line Voltage = 105 VAC

Input 3.0 MV rms — Deviation 0 db

Line Voltage = 125 VAC

Input 3.0 MV rms — Deviation .13 db

4. Selectivity and Bandwidth:

Resonant Frequency: 4000.4 cps
High Frequency 3 db Point: 1017 cps
Low Frequency 3 db Point: 983 cps

5. Noise:

With 200 Ohm in Input and Maximum Gain:
Output Noise Voltage .28 MV rms
Calculated Referred to the Input 25.5 MμV

Tested by _____ Engineer _____

87R1-5/59

Weinschel Engineering

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TWX Kensington, Maryland

Research & Development

Calibration Service

NIAGARA

B-4

PRELIMINARY INSTRUCTION MANUAL

FOR THE

BA-1C BOLOMETER PREAMPLIFIER

Serial No. 147 and above

CAL CERT PROP

IM #1, Rev. November, 1959

Step Attenuators
Coaxial Terminations
Coaxial Attenuator Pads
Coaxial Power & Pulse Power Pads

TRADE WE CO MARK
Reg. U.S. Pat. Office

Power Measuring Bridges
Bolometer Preamplifiers
Thermistor Mounts
Insertion Loss Test Sets

For Standards of Attenuation Use Weinschel Engineering Co.'s Coaxial Pads

PRELIMINARY

BA-1C INSTRUCTION MANUAL

List of Illustrations

Figure

1 Front Panel View BA-1C

2 Schematic , Drawing C110-8

3 Single Channel Block Diagram

Parts List

Application Note No. 4

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I Instruction Manual for BA-1C Preamplifier

Section One

General Introduction

1.1 Scope of Manual

This manual covers the description, theory of operation, operating procedure, and maintenance instructions for the Model BA-1C Bolometer Preamplifier.

1.2 Purpose of Equipment

This equipment was designed for general use in measuring r.f. power level ratios when used with a square law detector and other equipment to be described later.

Typical examples where r.f. level measurements are required are determinations of attenuation antenna patterns, insertion loss, amplifier gain, and standing wave ratios.

1.3 Specifications

1.3.1 Frequency: Audio - 1000 ± 2 cps R.F. - any for which bolometers, crystals or other required accessories are available.

1.3.2 Bandwidth: Not less than 25 cps and not more than 35 cps between 3 db points.

1.3.3 Voltage Gain: At least 10,000 at full gain position with an external output load of 1 megohm minimum and shall not change more than ± .1 db for a line voltage change of from 105 to 125 volts.

1.3.4 Maximum Output Voltage: 30 volts rms into a 1 megohm load.

1.3.5 Input impedance: 30,000 Ω ± 20%. For use with bolometer with dc resistance between 50 and 200 ohms, or for r.f. video crystals requiring no dc bias current.

1.3.6 Output Impedance: Less than 100,000 ohms. Load impedance should

be greater than 1 megohm for minimum distortion.

1.3.7 Equivalent Noise: Less than 30 millimicrovolts r.m.s. referred to the input when connected to a 200 ohm shielded wirewound resistor.

1.3.8 Bolometer bias current: Adjustable from zero to 10 ma dc. The bolometer may be connected or disconnected and the power switched on or off without damage to the bolometer.

1.3.9 Linearity: With a maximum input signal of 3 millivolts: 0.1 db over a 60 db range. With a maximum input signal of 0.3 millivolts: .02 db over a 40 db range. (A 60 db range corresponds to an r.f. ratio of 30 db.)

1.3.10 Controls: "Gain". Front panel mounted coaxial knob. Coarse control covers at least a 14:1 range in gain and the fine control approximately 5%.

Bolometer current adjust - screw slot adjustment available from front panel.

"Bolometer - crystal" selector - toggle switch disconnects bolometer bias from input.

Power "on-off" - Toggle switch with red pilot light indicator.

1.3.11 Connector: Input - BNC female, front panel mounted.

Output - BNC female, front panel mounted.

Power - Standard 115 volt, 2 wire recessed male cap on rear of chassis.

1.3.12 - Fuse: 3 amperes, mounted on rear of chassis

1.3.13 - Primary Power: 105-125 volts, 60 cps, 40 VA

1.3.14 - Ambient temperature: 15° C to 35° C

1.3.15 Dimensions: Standard relay rack mounting. Panel - 8 3/4" x 19". Maximum depth behind panel 13 1/2 in.

1.3.16 - Weight: 20 pounds

1.4 Description: The model BA-1C Bolometer Preamplifier is a high gain, low noise amplifier, selective to 1000 cps. It is designed to be used with

associated equipment such as a bolometer, or crystal square law detector in the input and a vacuum tube voltmeter or other high impedance measuring device in the output.

The input impedance is about 30,000 ohms and provides negligible loading on a 200 ohm bolometer. The input circuit contains a bolometer bias supply. It is provided with a meter indicating bolometer current. This current is continuously adjustable over a range from 0 to 10 ma. It may be turned off completely with the crystal-bolometer selector switch.

1.5 Unpacking and Preparation for Use.

The BA-1C is shipped in a double carton with three inches of packing material between the inner and outer cases. Normal care should be exercised when removing the instrument and packing material from the case. There should be no loose items with the exception of the line cord and this manual. Tubes are shipped in place.

After unpacking the instrument, examine it for mechanical damage. If any damage is found, notify the shipping company immediately.

Remove the bottom cover of the chassis and examine the leads connecting the floating chassis to insure that no lead has been broken in transit. Check the ground connections,

Examine the 3 ampere fuse. Be sure that all tubes are firmly seated.

Turn the bolometer bias control to its maximum counter-clockwise position.

The other equipment required will depend on the purpose for which the instrument is to be used.

1.6 Preliminary precautions.

Keep the coaxial input cable from the bolometer to the input of the BA-1C as short as conveniently possible. Under no circumstances, allow it to exceed three feet in length. Do not permit any coaxial cable to pass through a strong magnetic field at the modulating frequency since the cable shielding is ineffective against such low frequency magnetic disturbances. Do not place the BA-1C in the same metal rack as the audio modulator for the r.f. source.

Avoid ground loops when connecting shielded cables. If a stabilized voltage regulator is used keep it as far away as practicable from the test set-up.

Although the instrument is well shielded, do not operate it in or near high intensity r.f. fields.

Maintain line voltage within operating limits using an a.c. voltage regulator if necessary.

Set coarse and fine gain control to their maximum counter-clockwise position. Plug in line cord and switch on the power. Allow equipment to warm up for five minutes. Connect the bolometer cable to the input. If a bolometer is used, set the bolometer current with a screwdriver through the hole in the front panel until the meter indicates correct operating current for the bolometer used.

The instrument is now ready for use.

SECTION TWO

Theory of Operation

2.1 General

The use of an audio substitution method of measurement of r.f. insertion loss is described in "technique of Microwave Measurements" by C.G. Montgomery (Vol. 11 of the M.I.T. Radiation Lab. Series) pp 806-808 and 838-841.)

This method is based on the assumption that the application of a modulated r.f. signal to a biased bolometer results in a resistance variation in the bolometer that is proportional to the r.f. power applied. If this resistance variation is used to develop the input voltage to an amplifier or voltmeter, it is possible to measure power ratios at the bolometer input by measuring voltage ratios. Measurement can be accomplished over a limited range using

a well-calibrated voltmeter such that an N db change in audio level corresponds to an N/2 db change in the r.f. level.

If an attenuator is used in a substitution arrangement so that the indicator is only used as an index, high accuracy may be obtained with little operator skill.

2.2 Barretter.

A barretter is recommended with this equipment since its thermal time constant is short enough so that resistance variations follow the 1000 cycle modulation on the input r.f. signal. The barretter also follows a square law over an appreciable power range.

The barretter is biased with a fixed current. When r.f. power is applied, the barretter resistance varies in accordance with this power. If a constant current bias supply is used, the resistance variations are caused entirely by r.f. power variations. If the r.f. signal is 100% square wave modulated at an audio frequency, the audio voltage developed across the barretter is proportional to the r.f. power.

In the BA-1C, the bolometer bias circuit is well filtered to prevent power supply ripple or other variations from appearing on the signal. Besides, it allows the operator to connect and disconnect the barretter without danger of burnout due to transient current surges.

Crystal diodes may also be used as square law detectors if the signal is kept within required limits. They have the advantage of being less costly and less subject to burnout than bolometers. The BA-1C is equipped with a crystal bolometer selector switch which disconnects the bias supply from the input if the use of crystal detectors is desired.

2.3 The BA-1C Bolometer Preamplifier

2.3.1 Input circuit: In addition to the bolometer bias supply mentioned

in the preceding paragraph, the input is connected to the primary of a step-up input transformer. This is to provide an impedance transformation between the bolometer element and the first tube grid of the 1000 cps tuned amplifier. This transformer is tuned to 1000 cps. Together with a feedback system, this provides a resistive input impedance at 1000 cps, which is about 30,000Ω, which is in the load impedance range for video crystals. It also presents essentially an open circuit to the barretter to avoid any voltage transfer errors. The transformer is designed with an effective magnetic shield to keep noise pickup at a low level.

2.3.2 The 1000 cps Tuned Amplifier: This amplifier consists of V1 (6AU6) and V2 (5814) as shown in the schematic diagram, Figure 2. To make the equipment useful down to low r.f. levels, noise in the system must be kept to a minimum. Thermal noise is equal to $\sqrt{4RKT\beta}$ in r.m.s. voltage where:

R is effective circuit resistance
K is Boltzmann's constant
T is absolute temperature
β is bandwidth

From this formula we can see that we can reduce the noise voltage by reducing the bandwidth. Therefore the BA-1C has a very narrow bandwidth (less than 35 cps). This is accomplished by a twin tee feedback circuit tuned to the center frequency of 1000 cps. At frequencies outside the passband, a large amount of negative feedback is applied to the grid of V1 through the secondary of the input transformer T1. At resonance, the feedback is greatly reduced, giving the amplifier a sharp peak at that frequency. Coarse and fine gain controls are located between the two halves of V2 and after the feedback point so that a change in gain will not affect the bandwidth.

SECTION THREE

Operating Procedure

3.1 A Single Channel Set-up

The Model BA-1C can be used in the set up as shown in Figure 3 to measure insertion loss. The range of measurement depends on noise from the bolometer and input circuit, which determines the low level end and the linearity of the system which determines the high level end.

This set up can be used to measure up to 30 db radio frequency power ratio.

A 100% modulated r.f. source is required which is stable enough in frequency and power output to make accurate measurements possible. The power output should be at least 20 milliwatts.

A 30 db pad is inserted following the source to prevent reactions on the source by the insertion of the unit under test.

A matching device such as a double stub tuner should be added following the pad so that the unit under test may be measured between points having impedance exactly equal to its characteristic impedance. A slotted line and VSWR indicator is included since it is usually required that VSWR measurements be taken at the same time as insertion loss measurements. A bolometer or a crystal may be used to demodulate the signal. A second double stub tuner is added between the unit under test and the detector to insure low VSWR looking into the detector.

If a barretter is used as a detecting device, it is necessary to provide proper bias current and avoid exceeding the maximum power rating. For example, for a Polytechnic Research and Development Model 610A barretter the bias current for square law operation is 4.5 milliamperes and maximum power is 200 microwatts. This power will provide an audio voltage of approximately 2 millivolts into the BA-1C. If a crystal is used, select one which will provide square law

detection under the prevailing conditions. Disconnect bias current by flipping the bolometer-crystal selector to "crystal" position.

To make a measurement, set the substitution attenuator at a several db higher than the expected attenuation with unit to be tested not included in the set up.

The BA-1C gain control is adjusted to produce a convenient reading on the indicator. It is advisable to make this reading correspond to one of the fine division lines, making it easy to reset accurately.

The unit under test is then inserted as shown in Figure 3 and enough audio attenuation removed to return the meter to its original reading. The difference between the two settings of the audio attenuator is then equal to t he attenuation of the unit under test.

3.1.1 The R.F. Source: Since the BA-1C is tuned to 1000 cps with a fairly narrow bandwidth, it is necessary that the r.f. source be 100% square wave modulated at 1000 cycles. The stability of the modulating frequency is important as well as amplitude stability since variation in output during measurement will cause an error. Weinschel Engineering MS-type sources are available with stable internal 1000 cps square wave modulation covering the r.f. frequency range of 50 to 10,500 megacycles. In addition, Model MO-1A modulator is available for use with generators that do not have internal 1000 cps square wave modulation with sufficient stability. With an output capacity of 20 milliwatt into a 50 ohm load, 30 db of padding may be used following the generator. Additional padding may be used if sufficient power is available but in no case should less than 20 db be used. Weinschel Engineering MS-type sources are provided with amplitude stabilization by

sampling the incident power in the output line and feeding this back to the oscillator power supply.

3.2. Dual Channel Setup

To increase the accuracy, particularly when measuring low insertion loss, a dual channel set up may be used. In this type of set up a null detector is used to compare the signal between two channels. One channel has known components only and is used as the reference channel. The other contains the unit under test. This set up permits measurements up to 20 db with a precision of within .01 db per 10 db. By comparing two channels connected to a common source, small variations of the r.f. generator may be tolerated. Weinschel Engineering Model ND-1 is designed for use in such a set up and features a phase shifter with a 410 degree continuously adjustable range.

3.3. Extension of the Range Measurement.

In Section 3.1 above , using a single channel, the range is limited by noise and linearity to about 30 db. If greater than 30 db is to be measured, a partial r.f. substitution method may be used if sufficient r.f. power is available. A 20 db or 30 db pad is calibrated by the method of Section 3.1 first. Then the calibrated pad is substituted for the unknown, and a convenient output meter reading is set up with the BA-1C gain control. The unit under test is inserted as in Figure 3 in place of the calibrated pad.

The audio substitution attenuator isreset for the same meter reading as in Section 3.1. The unknown attenuation is equal to the difference between the two settings of audio attenuation plus the value of the calibrated pad. Care must be taken that the power is sufficient to overcome noise and still not overload the detector. This method may be used to measure up to 60 db if 200 milliwatt is available from the r.f. source at impedance Zo.

SECTION FOUR

Maintenance

4.1 Introduction

The Model BA-1C Preamplifier has been designed to require a minimum of maintenance. However, should trouble develop and service become necessary the normal procedure for maintenance of vacuum tube amplifiers applies.

4.2 General Maintenance

4.2.1 Tubes: The checks usually made to determine the conditions of vacuum tubes will suffice. On rare occasions selction of tube V1 (6AU6) or V2 (5814) may be necessary if noise level is high or if the amplifier has a tendency to microphonic.

4.2.2 Components: Resistance, capacitance and voltage values are shown in the schematic diagram, Figure 2. Voltage measurements were made using a 20,000 ohms per volt meter.

4.3 Performance Tests

If the BA-1C preamplifier is suspected of faulty performance, the following tests may be made to establish its agreement with the original specifications:

4.3.1 Gain: Check the gain by connecting a sine wave audio generator to the input jack of the amplifier, and a VTVM to the output. Adjust the generator frequency to 1000 cps and level to 1 millivolt. At least 10 volts should be observed at the output giving a voltage gain of 10,000.

4.3.2 Noise: After performing above test, set gain to exactly 10,000. Connect a shielded 200 ohm wirewound resistor to the input jack. A bolometer mount with no r.f. applied will suffice. Adjust bolometer bias control to 9.0 ma. The VTVM should not exceed 0.30 mv.

4.3.2 Audio Filter Network: A twin-tee net work is nsed in a feedback loop to determine the amplifier bandwidth. Between the 3 db points, this should be less than 35 cps and centered at 1000 cps. If bandwidth or center frequency are found to be outside the specification limits and the trouble is isolated to the filter network, do nct attempt to adjust, but return the unit to the factory for repairs.

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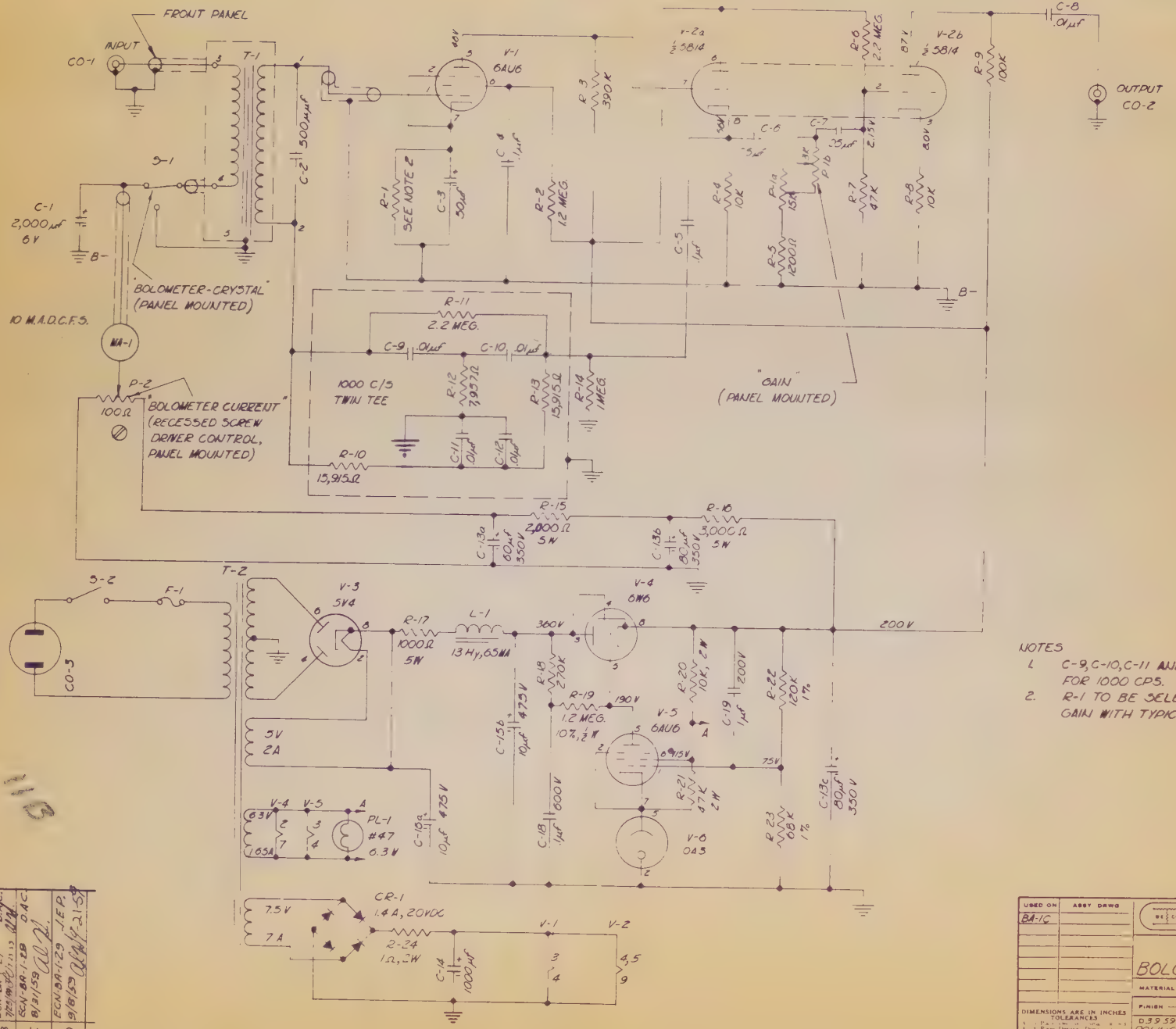
BA-1C

BOLOMETER PREAMPLIFIER



NOTES

1. C-9, C-10, C-11 AND C-12 TO BE SELECTED FOR 1000 CPS.
2. R-1 TO BE SELECTED FOR CORRECT GAIN WITH TYPICAL VALUE - 2.2 K.

REVISIONS			
A	ECN-BA-1-15 4 6 59	JEP	
B	ECN-BA-1-27		
C	ECN-BA-1-28 8/31/59		
D	ECN-BA-1-29 9/16/59	JEP	

USED ON	ASSY DRWG
BA-1C	

Weinschel Engineering
Kensington, Maryland

SCHEMATIC
BOLOMETER PRE-AMPLIFIER

MATERIAL —
FINISH —
DIMENSIONS ARE IN INCHES
TOLERANCES
D 9 59 POLING
SCALE —
C110-8
SIZE D

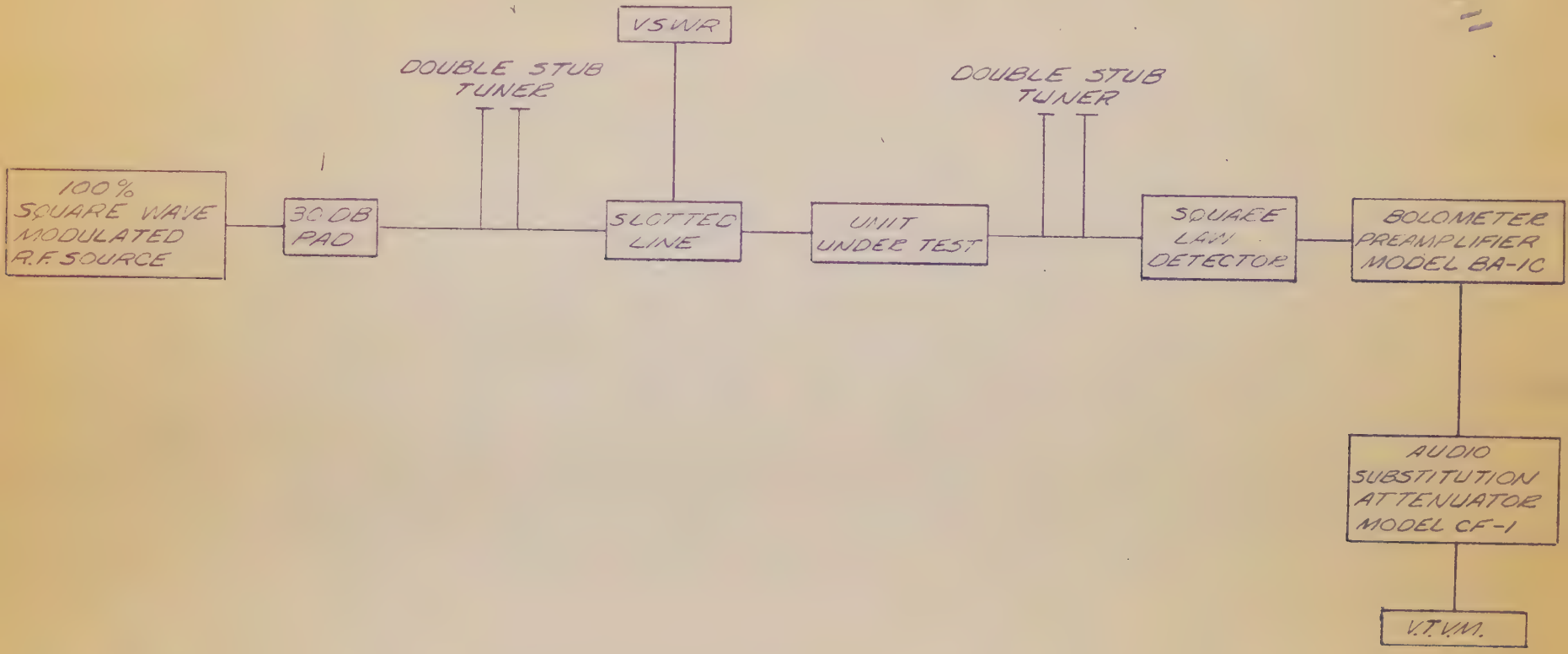


FIGURE 3

SINGLE CHANNEL BLOCK DIAGRAM

PARTS LIST FOR BA-1C

Symbol No.	Description	Weinschel Part No.
C1	CAPACITOR, Elect, 2,000 µf, 6v	32-1
C2	CAPACITOR, Silvered mica, 500 µµf	34-2-500
C3	CAPACITOR, Elect, 50µf, 25v	31-2
C4	CAPACITOR, Molded paper, .1 µf, 400v	33-2-R1
C5	Same as C4	
C6	CAPACITOR, Molded paper, .05 µf, 400v	33-2-R05
C7	Same as C6	
C8	CAPACITOR, Molded paper, .01 µf, 200v	33-2-R01
C9	CAPACITOR, Silvered mica, to be selected, Minimum value, .01 µf	
C10	Same as C9	
C11	Same as C9	
C12	Same as C9	
C13A,B,C	CAPACITOR, Elect, 3 section, 60/60/80 µf, 350v	32-10
C14	CAPACITOR, Elect, 1,000 µf, 15v	32-2
C15A,B	CAPACITOR, Elect, 2 section, 10/10 µf, 475v	32-11
C16	CAPACITOR, Molded paper, .1 µf, 600v	33-3-R1
C17	CAPACITOR, Metalized paper, 1 µf, 200v	33-6-1
CO1	CONNECTOR, Coaxial, UG-90/u	63-1
CO2	CONNECTOR, Coaxial, UG-928/u	63-14
CO3	CONNECTOR, AC power, 2 recessed male contacts	62-1
CR1	RECTIFIER, Selenium, bridge type, 20 vdc 1.4 amps	14-2

Symbol No.	Description	Weinschel Part No.
F1	FUSE, 3 amps	52-1-3
L1	CHOKE, Filter, 13 hy, 65 ma	40-40
MA1	METER, 0-10 madc	16-1
P1A,B	RESISTOR, Variable, ww, 2 section, 15k/3k, 3w	20-10
P2	RESISTOR, Variable, ww, 100 ohm, 4w	20-5
PL1	PILOT LAMP ASS'Y, with #47 bulb, 6.3v	51-4 & 50-1
R1	RESISTOR, Comp, to be selected, approx. value 2.2k ohm, 1/2w	
R2	RESISTOR, Comp, 1.2 megohm, 1/2w, 10%	25-1-1R2M
R3	RESISTOR, Comp, 390k ohm, 1/2w, 10%	25-1-390K
R4	RESISTOR, Comp, 10k ohm, 1/2w, 10%	25-1-10K
R5	RESISTOR, Comp, 1200 ohm, 1/2w, 10%	25-1-1200
R6	RESISTOR, Comp, 2.2 megohm, 1/2w, 10%	25-1-2R2M
R7	RESISTOR, Comp, 47k ohm, 1/2w, 10%	25-1-47K
R8	Same as R4	
R9	RESISTOR, Comp, 100k ohm, 1/2w, 10%	25-1-100K
R10	RESISTOR, ww, 15,915 ohm, 1/2w, .1%	26-2-15915
R11	Same as R6	
R12	RESISTOR, ww, 7957 ohm, 1/2w, .1%	26-2-7957
R13	Same as R10	
R14	RESISTOR, Comp, 1 megohm, 1/2w, 10%	25-1-1M
R15	RESISTOR, Comp, 2,000 ohm, 5w, 5%	26-6-2000
R16	RESISTOR, Comp, 3,000 ohm, 5w, 5%	26-6-3000
R17	RESISTOR, ww, 1,000 ohm, 5w, 5%	26-6-1000
R18	RESISTOR, Comp, 270k ohm, 1/2w, 10%	25-1-270K

Symbol No.	Description	Weinschel Part No.
R19	Same as R2	
R20	RESISTOR, Comp, 10k ohm, 2w, 10%	25-3-10K
R21	RESISTOR, Comp, 4,700 ohm, 2w, 10%	25-3-4700
R22	RESISTOR, Comp, 120k ohm, 1/2w, 1%	25-4-120K
R23	RESISTOR, Comp, 68k ohm, 1/2w, 1%	25-4-68K
R24	RESISTOR, ww, 1 ohm, 2 w, 10%	26- 17-1
S1	SWITCH, Toggle, 2 circuit	55-2
S2	SWITCH, Toggle, spst	55-1
T1	TRANSFORMER, Input	40-47
T2	TRANSFORMER, Power	40-56
V1	TUBE, Electron, 6AU6	10-2
V2	TUBE, Electron, 5814	10-7
V3	TUBE, Electron, 5V4	10-1
V4	TUBE, Electron, 6W6	10-107
V5	Same as V1	
V6	TUBE, Electron, 0A3	10-19

Application Note No. 4

DUAL CHANNEL INSERTION LOSS TEST SET

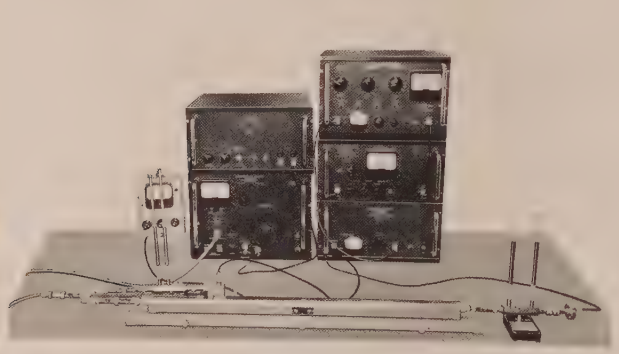
Introduction

The determination of the insertion loss of cable assemblies, r-f switches, the calibration of precision attenuators and similar precision insertion loss measurements requires a precise measurement of r-f power ratios.

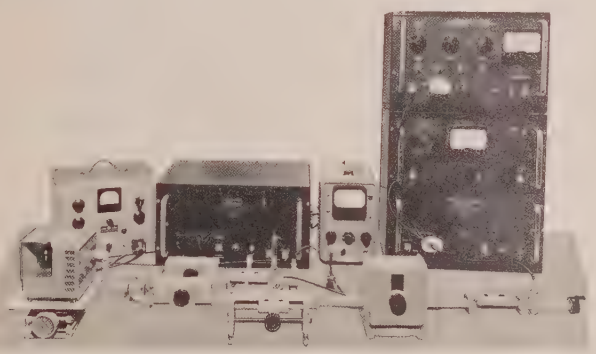
A very useful method of making such measurements uses a square wave modulated r-f source, square law detector and audio substitution attenuator as described in WECO Application Note No. 1. (1)* In this method, audio attenuation is substituted for r-f attenuation so as to maintain a constant audio output. In theory at least, it is only necessary to increase the sensitivity of the indicator to increase the precision of the measurement, providing all elements in the system have the required stability. It is this stability requirement that limits the precision that can be obtained with the system described in Application Note No. 1. (1) In particular, drift in the output level of the r-f source during the time required to substitute the unknown in the setup limits the precision attainable with that method.

To overcome this source of error, Weinschel Engineering has developed a Differential Null Detector, which, when used with the recommended accessories, permits measurements to 20 db which can be repeated with a precision of .01 db per 10 db. The sensitivity and short time stability permits the operator to estimate variations of .001 db. The system has an absolute accuracy of .02 db per 10 db when used with the recommended accessories. This instrument and the method of measurement are the subjects of this application note.

** Numbers in () refer to items in the bibliography at the end of this application note.*



Coaxial



Waveguide

The Dual Channel Insertion Loss Test Set

The Method

A stable radio frequency source of the proper frequency is 100% square wave modulated at a frequency of 1 kilocycle and is divided into two channels: the measurement channel and the reference channel. The two r-f signals derived from the same generator are detected in two bolometers which are operated in their square law region, i.e., the voltage at the modulation frequency (i.e. 1000 cycles per second) developed across the bolometer is proportional to the r-f power absorbed by the bolometer. (2, 3) It is important that the bolometers be properly matched to the r-f line either by the use of transmission line tuners or the use of a broad band mount and that they not be driven out of the square law region. The 1 kc signals from the bolometers are then amplified and applied to the Differential Null Detector, Model ND-1.

The location of the various units in the system and their function can be understood by reference to the following explanation and the block diagram. Following the bolometer in the reference channel is Bolometer Preamplifier, Model BA-1 that serves to supply to the Differential Null Detector a 1 kc voltage with an amplitude that is accurately proportional to the power output of the r-f signal source. The measurement channel contains a slotted line, provisions for insertion of the unit under test, a bolometer mount and an Attenuation Calibrator, Model BA-5. The output of the BA-5 is applied to the other input of the Differential Null Detector. The BA-5 contains a precision audio substitution attenuator followed by a linear 1 kc amplifier. In making an insertion loss measurement,audio attenuation is substituted for the attenuation of the unit under test.

To measure insertion loss, the precision audio substitution attenuator in the BA-5 Attenuation Calibrator is first set to include at least slightly more at-

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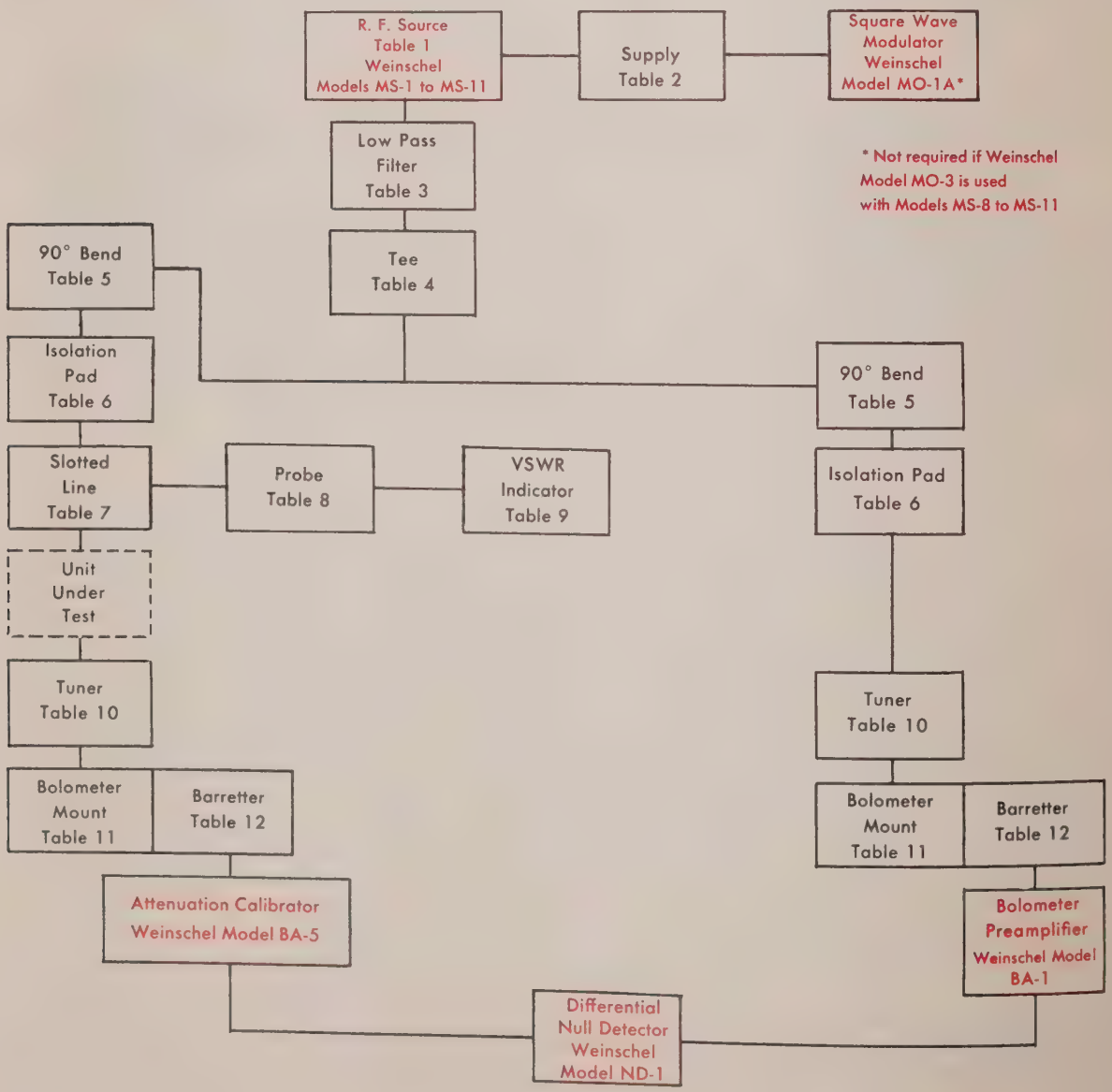
DUAL CHANNEL INSERTION LOSS TEST SET

tenuation than the expected insertion loss of the unit to be tested or calibrated. The gain in the reference channel and the phasing adjustments on the Differential Null Detector, ND-1 are adjusted to produce a null reading on the ND-1. The unit under test is then inserted in the measurement channel as shown in the block diagram. Audio attenuation is removed until a null indication on the ND-1 is again obtained. The amount of audio attenuation removed is a measure of the insertion loss of the unit under test. It will be noted that the output of the measurement channel is not necessarily returned to the same level as before insertion of the unit under test, but rather to a value to produce a null reading on the ND-1. If the r-f source output has drifted since the first null adjustment, the reference channel output has changed by a proportionate amount and the measurement channel output required to produce a null is automatically compensated.

The design of the Differential Null Detector is such that the front panel indicator displays a highly non-linear behavior. If the two inputs to the ND-1 are very different, the amplifier in the ND-1 assumes approximately a logarithmic characteristic and the meter is not driven off scale. As the signal level is adjusted to produce a null indication, the proper direction of the adjustment can be determined and as the null is approached the sensitivity of the indication automatically increases to allow a precise adjustment to be made.


R. F. Source Table 1 Weinschel Models MS-1 to MS-11
Supply Table 2
Square Wave Modulator Weinschel Model MO-1A*
* Not required if Weinschel Model MO-3 is used with Models MS-8 to MS-11
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Tuner Table 10
Bolometer Mount Table 11
Barretter Table 12
Bolometer Preamplifier Weinschel Model BA-1
Differential Null Detector Weinschel Model ND-1

TABLE 1 R.F. SOURCES

Frequency Range kmcs	Manufacturer	Model Number	Power Supply Required
0.05 – 0.25	Weinschel	MS-1	None
0.25 – 0.92	Weinschel	MS-2	None
0.90 – 2.00	Weinschel	MS-3	None
0.90 – 2.20	Weinschel	MS-8	Weinschel Model MO-3*
1.20 – 3.75	Raytheon	2-K-28	See Table 2
1.99 – 2.10	Varian	X-17	"
2.00 – 4.20	Weinschel	MS-4	None
2.00 – 4.20	Weinschel	MS-9	Weinschel Model MO-3*
2.66 – 3.31	Sperry	2-K 41	See Table 2
3.3 – 4.20	Sperry	2-K 42	"
4.0 – 7.30	Weinschel	MS-5	None
4.0 – 7.30	Weinschel	MS-10	Weinschel Model MO-3*
4.2 – 5.70	Sperry	2-K 43	See Table 2
5.7 – 7.50	Sperry	2-K 44	"
7.2 – 10.50	Weinschel	MS-6	None
7.2 – 10.50	Weinschel	MS-11	Weinschel Model MO-3*
7.5 – 10.3	Sperry	2-K 39	See Table 2
8.2 – 12.4	Varian	X-13	"
10.0 – 15.0	Varian	V-39-C	See Table 2
12.4 – 17.5	Varian	X-12	"
15.0 – 21.0	Varian	V-40-C	"
22.0 – 25.0	Raytheon	233	"
22.0 – 25.0	Varian	VA-96	"
26.3 – 31.3	Raytheon	QK-140	"
30.0 – 35.3	Raytheon	QK-141	"
33.0 – 37.5	Raytheon	QK-141	"
33.5 – 36.2	Raytheon	QK-291	"
34.0 – 35.6	Varian	VA-97	"
34.9 – 40.6	Raytheon	QK-142	"
37.5 – 44.1	Raytheon	QK-226	"
41.7 – 50.0	Raytheon	QK-294	"
50.0 – 60.0	Raytheon	QK-295	"

* Includes Modulator

TABLE 2
KLYSTRON POWER SUPPLIES

PRD	801-A
Sperry	SX-12
FXR	Z815A

The Instruments

The r-f power source must be stable in both frequency and output level so that no change in the characteristics of the unit under test will occur during the measurement. The use of the dual channel setup reduces the effect of any change in the source output insofar as the measuring equipment is concerned but if the unit under test is non-linear, its characteristics may change. The same considerations apply with regard to frequency variations, except that if the impedance characteristics of the bolometers are not the same, and in general they are not, a small change in frequency can result in an appreciable variation in the balance between the two channels.

The r-f power sources must be 100% square wave modulated at a frequency of 1000 cycles per second. It is important that this frequency be very stable, since the elements in both channels of the setup are tuned to this frequency and at the center of the band the phase characteristic has its greatest slope. A very small change in modulation frequency can, therefore, result in a large change in the phase of the signal applied to the Differential Null Detector. For the two signals applied to the inputs of the Differential Null Detector to produce a null, not only must their amplitudes be equal, but they must be properly phased. A small change in the modulation frequency will in general result in an appreciable change in the relative phase between the signals from the two channels. It is recommended that Weinschel Engineering's Model MO-1A Modulator be used in this application. It supplies a square wave, at a frequency of 1000 ± 0.1 cycles per second that is derived from a tuning fork oscillator. The amplitude is sufficient to fully modulate most test oscillators and klystrons.

Both channels have a pad immediately following the divider to insure a constant source impedance and prevent any reaction between the generator and the unit under test or between channels.

The linear range of the reference channel is not critical since it operates at a substantially constant level throughout the measurement. Convenience, however, dictates a fairly wide dynamic range and a variable gain to allow easy adjustment of the signal level at the output of the reference channel. It is also necessary that the gain of this channel be very stable. Weinschel Engineering's Model BA-1 Amplifier fulfills these requirements.

The measurement channel is similar to the system

TABLE 3
LOW PASS FILTERS

Cutoff Frequency kmcs	Manufacturer	Model Number
.044	Sierra	184
.076	Sierra	184
.135	Sierra	184
.230	Sierra	184
.400 .5	Sierra NARDA	184 /3010-500
.400	Bird	844
.7-1.0	H.P./NARDA	360-A/3010-1000
1.2	Bird	819-1200
1.2	H.P.	360-B
2.2 2.1	H.P. NARDA	360-C 3010-2100
4.1 4.2	H.P. NARDA	360-D 3010-4200

TABLE 4
TEES
COAXIAL
UG-28A/U
UG-107A/U, B/U
WAVEGUIDE—SHUNT TYPE—H-PLANE

Frequency Range, kmc	Manufacturer's Model Number		
	FXR	Narda	PRD
2.6 — 3.95	S-621-A	934	
3.95 — 5.85	H-621-A	933	
5.85 — 8.2	C-621-A	932	
7.05 — 10.0	W-621-A	931	
8.2 — 12.4	X-621-A	930	465
12.4 — 18.0	Y-621-A	929	
18.0 — 26.5	K-621-A	928	
26.5 — 40.0	U-621-A	V-927	
33.0 — 50.0	Q-621-A	Q-927	
50.0 — 75.0	M-621-A	M-927	487
60.0 — 90.0	E-621-A	E-927	

TABLE 5
90° BENDS
COAXIAL
UG-27A/U
UG-27B/U
UG-27C/U
WAVEGUIDE—H-PLANE

Frequency Range, kmc	Manufacturer's Model Number		
	FXR	Narda	PRD
2.6 — 3.95	S-624-B	354-H	
3.95 — 5.85	H-624-B	353-H	
5.85 — 8.2	C-624-B	352-H	
7.05 — 10.0	W-624-B	351-H	
8.2 — 12.4	X-624-B	350-H	463
12.4 — 18.0	Y-624-B	349-H	
18.0 — 26.5	K-624-B	348-H	
26.5 — 40.0	U-624-B	V-347-H	
33.0 — 50.0	Q-624-B	Q-347-H	
50.0 — 75.0	M-624-B	M-347-H	486
60.0 — 90.0	E-624-B	E-347-H	

described in Application Note No. 1. In place of separate units in the form of a Bolometer Preamplifier, BA-1, and Audio Substitution Attenuator, CF-1, a Model BA-5 Attenuation Calibrator is used. In this unit the Audio Substitution Attenuator precedes the amplifier so the amplifier operates at substantially a constant level during any one measurement. This eliminates any non-linearity of the amplifier as a possible source for error in the measurement. The output of the BA-5 supplies one input of the Differential Null Detector. The output indicator on the BA-5 is used only to monitor the level of the output of the measurement channel to insure that everything is operating in the proper range.

TABLE 6
ATTENUATORS
ISOLATION–RANGE EXTENSION

COAXIAL

Frequency Range kmc	Manufacturer	Model Number
D.C.- 1.0	Weinschel	50
D.C.- 1.0	Weinschel	11
1.0-12.4	Weinschel	210
1.0-12.4	Weinschel	503

WAVEGUIDE

Frequency Range kmcs	Manufacturer's Model Number			
	FXR	H.P.	Narda	PRD
2.6 – 3.95	S-151-A	S-375-A	734	171
3.95 – 5.85	H-151-A	G-375-A	733	162
5.85 – 8.2	C-151-A	J-375-A	732	161
7.05 – 10.0	W-151-A	H-375-A	731	160
8.2 – 12.4	X-151A	X-375-A	730	159
12.4 – 18.0	Y-151-A	P-375-A	729	189
18.0 – 26.5	K-151-A	K-375-A	728	190
26.5 – 40.0	U-151-A	R-375-A	V-727	191
33.0 – 50.0	Q-151-A		Q-727	
50.0 – 75.0	M-151-A		M-727	179
60.0 – 90.0	E-151-A		E-727	

TABLE 7
SLOTTED LINES
COAXIAL

Frequency Range kmcs	Manufacturer	Model Number
.02 – .6	B.J. Electronics	65
.1 – 3.0	B.J. Electronics	62
.5 – 4.0	H.P.	805-A
.45 – 4.0	Narda	230-N, 230-C, 230-⅝, 230-⅞, 230-SC
1.0 – 4.0	FXR	N-101-A†
1.0 – 4.0	PRD	215-A†
1.5 – 12.4	Narda	231-N, 231-C, 231-TNC†
3.0 – 12.0	H.P.	806-B†
4.0 – 10.0	FXR	N-201-B†
4.0 – 10.0	PRD	205-A†

WAVEGUIDE

Frequency Range kmcs	Manufacturer's Model Number			
	FXR	Narda	H.P.	PRD
2.60 – 3.95	S-101-A†	224†	S-810-†	209-A†
3.95 – 5.85	H-101-A†	223†	G-810-B/†	201-A†
5.85 – 8.2	C-101-A†	222†	J-810-B/†	204-B
7.05 – 10.0	W-101-A†	221†	H-810-B/†	202-B†
8.2 – 12.4	X-101-A†	220†	X-810-B/†	203-D†
12.4 – 18.0	Y-102-A	219†	P-810B/†	210-A
18.0 – 26.5	K-102-A	218*	P-815-A†	211-A
26.5 – 40.0	U-102-A	V-217*	K-815-A†	212-A
33.0 – 50.0	Q-103-A	Q-217*	R-815-A†	
50.0 – 75.0	M-103-A	M-217*		216
60.0 – 90.0	E-103-A	E-217*		

/Used with Universal Probe Carriage.

† Requires tuning probe—see table 8.

* Requires Detector Mount.

TABLE 8
PROBES

Freq. Range, kmcs	Manufacturer	Model Number
1.0 – 12.4	FXR	B-200-A
1.0 – 12.4	PRD	250-A tunable
.9 – 18.0	Narda	229 tunable
8.0 – 18.0	H.P.	444-A untuned
12.4 – 40.0	H.P.	446-A untuned

TABLE 9
VSWR INDICATORS

H.P.	415-B
PRD	277
FXR	B-810-A
Narda	441

TABLE 10
COAXIAL TUNERS

Frequency Range, kmcs	Manufacturer	Model Number
.20 – 2.0	Weinschel	DS-109LL
.40 – 4.0	Weinschel	DS-109L
.75 – 10.0	Weinschel	DS-109

WAVEGUIDE TUNERS

Frequency Range, kmcs	Manufacturer's Model Number			
	H.P.	PRD	Narda	FXR
2.60 – 3.95	S-870-A	309-A	964	S-311-A S-312-A
3.95 – 5.85	G-870-A	300-A	963	H-311-A H-312-A
5.85 – 8.20	J-870-A	305-A	962	C-311-A C-312-A
7.05 – 10.0	H-870-A	302-B	961	W-311-A W-312-A
8.2 – 12.4	X-870-A X-880-A	303-A	960	X-311-A X-312-A
12.4 – 18.0	P-870-A P-880-A	314-A	959	Y-311-A Y-312-A
18.0 – 26.5	K-870-A K-880-A	313-A	958	K-312-B
26.5 – 40.0	R-870-A R-880-A	312-A	V-957	U-312-B
33.0 – 50.0			Q-957	Q-312-B
50.0 – 75.0		323	M-957	M-312-B
60.0 – 90.0			E-957	E-312-B

A bolometer bias current supply is included in the Model BA-5. The bias current is derived from the plate voltage supply through dropping resistors to the barretter. In order to avoid any ripple components in the d-c supply, four RC networks are employed for decoupling. The impedance of the d-c supply at 1000 cycles per second is high compared to the impedance of the audio substitution attenuator to prevent loading of the barretter by the power supply. The biasing circuit includes a crystal diode in parallel with the barretter to limit the peak discharge current when the barretter is connected, thus preventing burnout of the barretter due to transients arising during connection or disconnection of the a-c power to the instrument or connection or disconnection of the barretter to the instrument.

The attenuation measurement is made by substituting attenuation in the audio portion of the measurement channel for the r-f attenuation of the unit under test. Since the audio voltage developed across the barretter is proportional to r-f power, a 30 db change in r-f level produces a 60 db change in audio level. The BA-5 provides an a-f attenuation range of 104 db corresponding to 52 db in r-f. Since the BA-5 is designed specifically for this application, it is calibrated directly in changes in r-f power level.

The last instrument to be considered is the Differential Null Detector, Model ND-1. This unit com-

TABLE 11
COAXIAL BOLOMETER MOUNTS

Frequency Range kmc	Input Connector	Transmission Line	Use Barretter Type No.	Manufacturer's Model Number				
				FXR	H.P.	Narda	PRD	Notes
0.02 – 1.5	UG-23/U	3⅝"	2 of 3		476-A	560		a
0.10 – 10.0	UG-21/U	3⅝"	1,2	N-210A				b, c
0.10 – 10.0	UG-21/U	3⅝"	1,2	N-210B				b
0.50 – 10.0	UG-23/U	3⅝"	8			561	627-A	a
0.50 – 10.0	UG-23/U	3⅝"	9			561		a
1.0 – 4.0	UG-23/U	3⅝"	4		475-B			d
1.0 – 10.0	UG-21/U	3⅝"	1,2				612-A	d
1.0 – 10.0	UG-21/U	3⅝"	1,2				613	b, c
1.0 – 10.0	UG-21/U	3⅝"	1,2				613-M	b

a—Broadband
b—Requires external tuning
c—Requires external DC return
d—Self-contained tuning

WAVEGUIDE BOLOMETER MOUNTS

Frequency Range, kmc	Input Connector	Transmission Line	Use Barretter Type No.	Manufacturer's Model Number			
				FXR	H.P.	Narda	PRD
2.6 – 3.95	UG-53/U	RG-48/U	4		S-485-A	514	
2.6 – 3.95	UG-53/U	RG-48/U	12			534†	
3.95 – 5.85	UG-149/U	RG-49/U	2, 4		G-485-B	513	
3.95 – 5.85	UG-149/U	RG-49/U	12			533†	
5.85 – 8.20	UG-344/U	RG-50/U	2, 4		J-485-B	512	
5.85 – 8.20	UR-344/U	RG-50/U	12			532†	
7.05 – 10.0	UG-51/U	RG-51/U	2, 4		H-485-B	511	
7.05 – 10.0	UG-51/U	RG-51/U	12			531†	
8.2 – 12.4	UG-39/U	RG-52/U	2, 4		X-485-B	510	
8.2 – 12.4	UG-39/U	RG-52/U	2	X-211-A			
8.2 – 12.4	UG-39/U	RG-52/U	12			530†	
12.4 – 18.0	UG-419/U	RG-91/U	2, 4, 5		P-485-C	509	
12.4 – 18.0	UG-419/U	RG-91/U	11			529†	
12.4 – 18.0	UG-419/U	RG-91/U	5	Y-205-B			
18.0 – 26.5	UG-425/U	RG-66/U	10				620
18.0 – 26.5	UG-595/U	RG-66/U	10				620-F-1
18.0 – 26.5	UG-425/U	RG-53/U	5	K-205-B			
18.0 – 26.5	UG-595/U	RG-53/U	5	K-205-F			
26.5 – 40.0	UG-599/U	RG-96/U	6	U-205-F			
26.5 – 40.0	UG-599/U	RG-96/U	7	U-206-F			
26.5 – 40.0	UG-599/U	RG-96/U	10				618-F-1
26.5 – 40.0	UG-381/U	RG-96/U	10				
33.0 – 50.0	UG-383/U	RG-97/U	7	Q-206-B			
50.0 – 75.0	UG-383/U	RG-98/U	7	M-206-B			
60.0 – 90.0	UG-387/U	RG-99/U	7	E-206-B			

† Fixed Tuned

pares the two 1000 cycle per second signals at the outputs of the two channels. As previously mentioned, before it is possible to obtain a null, it is necessary to adjust the two signals to the same amplitude and the relative phase of the two signals until they are exactly in phase. Both signals are derived from the same square wave modulated r-f source and would have a fixed phase relationship if it were not for the possibility of a difference in the phase shift in the audio portions of the two channels. To compensate for this, a variable phase shifter is provided in one channel of the ND-1. With the phase shifter and a phase reversing switch, the relative phase can be adjusted over the complete range of 360 degrees. The design of the phase shifter is such that variation of the phase over this range results in a negligible change in amplitude. Following the phase shifter, the two signals are fed to a differential transformer which produces an output proportional to the difference between the two signals.

The phase shifter, differential transformer and associated networks are designed for the fundamental of the 1000 cycle per second signal. Any harmonics of this signal which may be present in the measurement or reference channel will not, in general, be balanced out in the differential transformer and will pass the amplifier to give a reading on the unbalance indicator and thus reduce the sensitivity of the measurement. To prevent this, a filter is used to reject all harmonics of the 1000 cycle per second signal. It also prevents

broadening of the null due to any 60 cycle or 120 cycle hum that might be present on the signal.

Since it is desirable that the unbalance indicator operate for large as well as small unbalance signals without overloading, a lin-log amplifier is used. The small signal gain of this amplifier is enough to produce at least a 10% of full scale deflection for variations of attenuation of .003 db in the r-f portion of the measurement channel.

The use of this type of amplifier obviates the need for a gain control and at the same time allows an accurate null indication. It also has the advantage of not going off scale with an accidental misadjustment as a null is being approached.

The amplifier is followed by a rectifier circuit with the unbalance indicator meter between two cathode followers, one of which is driven by the rectified signal. This arrangement balances out the effect of small plate and heater voltage fluctuations on the meter balance point.

TABLE 12 – 200 OHM BARRETTERS

* Type	Fits Mount For	Shielded	Unshielded	DC Bias MA	Manufacturer's Model Number FXR	Narda	PRD	Sperry	Special Features	For Coaxial	For Waveguide
1	1N21	x		4.5						x	
2	1N21		x	4.5	Z-220-C		610-A			x	x
2	1N21		x	4.5		N-610-B-4.5				x	x
2	1N21		x	8.75	Z-220-A					x	x
2	1N21		x	8.25	Z-220-B					x	x
2	1N21		x	8.75		N-610-B				x	x
3	1N21		x	8.75		N-610-B-100			Use 2	x	x
4	0.193" dia. 0.812" long		x	8.75		N-821-B		821		x	x
5	1N26	x		4.5			614		12.4-26.5 kmc		x
5	1N26	x		8.75	Z-221-A				12.4-40 kmc		x
6	Modified 1N26	x		8.75	Z-221-B				26.5-40 kmc		x
7	1N53	x		8.75	Z-222-A				26.5-90 kmc		x
8	Special Mica Strip		x	4.5		N-603-4.5	631-C		0.5-10 kmc	x	
9	" "		x	8.75		N-603			0.5-10 kmc	x	
10	" "		x	4.5			617		18-40 kmc	x	x
11	Miniature		x	8.75		N-604			8.2-18 kmc		x
12	1N21		x	8.75		N-605			(Low Inductance) 1.1-10 kmc		x

The barretters with lower bias current require about 2 db less r-f for the same 1000 cps output. They may burn out if 4 milliwatts r-f power are added while those with higher bias current may burn out if 16 milliwatts r-f power are added.

* *See COAXIAL BOLOMETER MOUNTS, Table 11.*

Conclusion

A system has been described that is suitable for measurement of insertion loss up to 20 db with an accuracy of .02 db per 10 db at any frequencies for which power sources and bolometers are available. This range is limited by commercially available bolometer mounts to from 20 mcs. to 90,000 mcs. The application of Weinschel Engineering's Attenuation Calibrator, Model BA-5 and Differential Null Detector, Model ND-1 is described. These units were specifically designed for this type of measurement. To increase the range of insertion loss measurements, partial r-f substitution can be used providing sufficient power from the source is available. For example the range can be extended to 40 db if the source can deliver an output of 200 milliwatts.

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WEINSCHEL ENGINEERING
KENSINGTON, MARYLAND
TEST RECORD

BOLOMETER PREAMPLIFIER — MODEL BA-1C

DATE 3-18-60 — SERIAL NUMBER 255

CUSTOMER _____ — JOB NUMBER _____

1. Gain:

Input = 1.0 MV — Output 10.5 V rms

2. Linearity:

Input	DEVIATION	Deviation from Linear
3 MV	0 db	0 db
-2 db	0 db	Less than .05 db
-6 db	+.005 db	" " " db
-10 db	+.007 db	" " " db
-14 db	+.009 db	" " " db
-18 db	+.010 db	" " " db
-24 db	+.011 db	" " " db
-30 db	+.013 db	" " " db

3. Gain Stability:

Line Voltage = 105 VAC

Input 3.0 MV rms — Deviation 0 db

Line Voltage = 125 VAC

Input 3.0 MV rms — Deviation .13 db

4. Selectivity and Bandwidth:

Resonant Frequency: 4,000.4 cps
High Frequency 3 db Point: 1017 cps
Low Frequency 3 db Point: 983 cps

5. Noise:

With 200 Ohm in Input and Maximum Gain:
Output Noise Voltage .28 MV rms
Calculated Referred to the Input 25.5 MμV

Tested by _____ Engineer _____

87R1-5/59

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